Published by Elsevier Inc.
ISSN 0735-1097/03/$30.00
doi:10.1016/S0735-1097(03)00640-5

Waiting Times, Revascularization Modality, and Outcomes After Acute Myocardial Infarction at Hospitals With and Without On-Site Revascularization Facilities in Canada

David A. Alter, MD, PhD,*†‡ Jack V. Tu, MD, PhD,*‡§||¶# Peter C. Austin, PhD,*¶
C. David Naylor, MD, DPhil*‡||¶#
Toronto, Canada

OBJECTIVES This study was designed to determine whether admission to a Canadian hospital with on-site revascularization (invasive hospital) affected revascularization choice, timing, and outcome compared with community (non-invasive) hospitals.

BACKGROUND Health care systems in Canada are characterized by relative restraint in diffusion of tertiary cardiovascular services, with capacity for revascularization procedures concentrated in large regional referral centers.

METHODS We used linked administrative data and a clinical registry to follow-up 15,166 Ontario patients who underwent revascularization within the year after their index acute myocardial infarction (MI). Outcomes included recurrent urgent cardiac hospitalization, hospital bed-days, and death within the same year after the index admission. We adjusted for age, gender, socioeconomic status, illness severity, attending physician specialty, and academic hospital affiliation.

RESULTS After adjusting for baseline factors, patients admitted to invasive hospitals were more likely to receive angioplasty than bypass surgery (adjusted odds ratio: 1.85; 95% confidence interval: 1.68 to 2.04, $p < 0.001$). The converse pattern was seen for patients admitted to community hospitals. Median revascularization waiting times were significantly shorter at invasive hospitals (12 vs. 48 days, $p < 0.001$). Patients admitted to invasive hospitals had fewer cardiac re-admissions (41.5 vs. 68.9 events per 100 patients, $p < 0.001$) before their first revascularization and consumed fewer hospital bed-days (379 vs. 517 per 100 patients, $p < 0.001$). There were no differences in outcomes beyond revascularization.

CONCLUSIONS Outcome advantages associated with timely post-MI revascularization highlight the importance of organizing revascularization referral networks and facilitating access to revascularization for patients with acute coronary syndromes admitted to community hospitals in Canada. (J Am Coll Cardiol 2003;42:410–9) © 2003 by the American College of Cardiology Foundation

Patients admitted to hospitals with on-site revascularization capability undergo coronary artery bypass graft surgery or percutaneous transluminal coronary angioplasty earlier and more frequently than those admitted to community hospitals (1–4). Accumulating evidence suggests that delays in revascularization are undesirable in eligible patients (5–9). This poses challenges for the optimal organization of cardiac care in universal health systems where procedural capacity tends to be concentrated in regional referral centers.

See page 420

We sought to confirm the extent of differences in timing of intervention after myocardial infarction (MI) between hospitals with (invasive) and without (non-invasive) revascularization. We hypothesized that any differences in timing might be attributable in part to factors such as a higher proportion of attending cardiologists and early use of angioplasty in invasive hospitals (10). We also hypothesized that differences in procedural waiting times could be associated with a higher rate of complications among patients awaiting revascularization (7,8,11).

From the *Institute for Clinical Evaluative Sciences; †Division of Cardiology, Schulich Heart Centre, Sunnybrook and Women's College Health Sciences Centre and the University of Toronto; ‡Faculty of Medicine, University of Toronto; §University of Toronto Clinical Epidemiology and Health Care Research Program (Sunnybrook and Women's College Site); ||Division of General Internal Medicine, Sunnybrook and Women's College Health Sciences Centre and the University of Toronto; ¶Department of Public Health Sciences, University of Toronto; and the #Department of Health Policy, Management, and Evaluation, University of Toronto, Toronto, Canada. Dr. Alter is a New Investigator of the Canadian Institutes of Health Research and the Heart and Stroke Foundation of Canada. Dr. Tu is supported by a Canada Research Chair in Health Services Research. This project was supported by an operating grant from the Canadian Institutes of Health Research (CIHR). The Institute for Clinical Evaluative Sciences is supported in part by a grant from the Ontario Ministry of Health and Long-Term Care. The results, conclusions, and opinions are those of the authors, and no endorsement by the Ministry, the Institute, or the CIHR is intended or should be inferred.

Manuscript received November 4, 2002; revised manuscript received December 20, 2002, accepted February 6, 2003.

Abbreviations and Acronyms

ACE	= angiotensin-converting enzyme
AMI	= acute myocardial infarction
CI	= confidence interval
ICD-9	= International Classification of Diseases-9th Revision
MI	= myocardial infarction
OMID	= Ontario Myocardial Infarction Database
OR	= odds ratio
RR	= relative risk

METHODS

System context. The Canadian health insurance system provides universal coverage for basic in-hospital care, without charges at point of service or a parallel private system. In Ontario, funding for angioplasty and bypass surgery is based on population-based target rates (with benchmark per capita rates for bypass and angioplasty each set at 100 per 100,000 adults during the study period). Population-based capacity for revascularization in Ontario is markedly lower than in the U.S. and similar to many European nations, albeit higher than the U.K., Spain, and Portugal (12). Such services are regionalized to selected tertiary cardiac centers with the expectation that populations residing within surrounding catchment areas are equitably serviced. During the study period, nine of 201 acute-care hospitals (invasive centers) throughout Ontario offered on-site angioplasty and bypass facilities.

Data sources. The Ontario Myocardial Infarction Database (OMID) project links all of Ontario's major health care administrative databases with follow-up tracking of out-of-hospital mortality over time, regardless of site of death. Complete details regarding the construction of the OMID cohort, including eligibility criteria and coding accuracy, have been published elsewhere (13). For this study, the cohort was also linked to the Cardiac Care Network of Ontario registry as a source of supplemental clinical and angiographic information for patients who underwent coronary bypass surgery in Ontario. The study was approved by the Research Ethics Board of the Sunnybrook and Women's College Health Sciences Centre.

Cohort. The cohort consisted of any patient admitted to hospital with a most responsible diagnosis of acute myocardial infarction (AMI) (International Classification of Diseases-9th Revision [ICD-9] code 410) in Ontario between April 1, 1994, and March 31, 1998, inclusive, who received myocardial revascularization procedures within the first 12 months after their infarct. Each patient was represented only once in the cohort. Revascularization procedures (as defined as the first of either bypass surgery or angioplasty) were assessed until one year after MI in order to allow for appropriate post-MI risk stratification and waiting times (14,15). We excluded patients (4.5% of the cohort) admitted to institutions with on-site angiography-only facilities and those (3.5%) for whom no information regarding the attending physician was available.

To preclude confusion of the results by differential use of primary or salvage angioplasty as a primary modality for treatment of AMI, we excluded all patients receiving revascularization on the same day as their AMI admission (Fig. 1). A re-analysis of our data with the inclusion of such patients did not significantly alter our results.

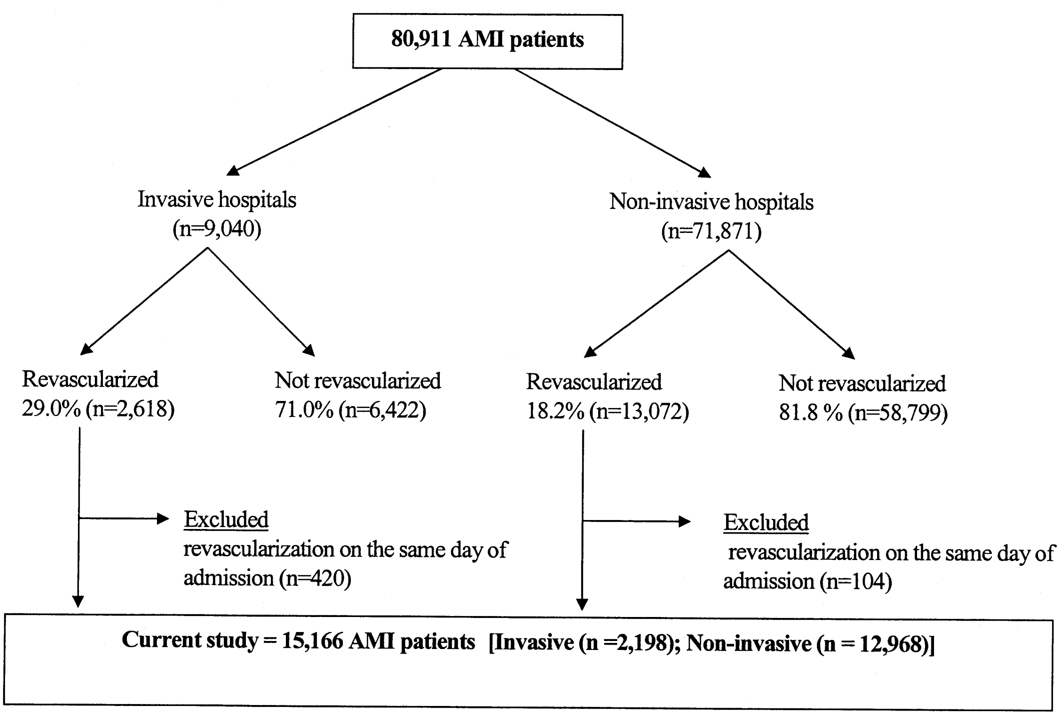

Figure 1. Study flow chart. AMI = acute myocardial infarction.

Hospital, physician, and patient characteristics. Based on our a priori hypotheses, we focused on the presence or absence of on-site revascularization capacity at the admitting hospital. Patients were categorized according to their initial admitting hospital, regardless of downstream transfers. Among 12,968 patients initially admitted to non-invasive hospitals, 5,208 patients (40.2%) were transferred to other institutions during the index hospital stay. Each patient's initial length of hospital stay during the index AMI admission reflected the total number of days spent at both the transferring and receiving hospitals.

Baseline patient characteristics including age, gender, and disease severity were obtained from discharge abstracts of the index AMI admission. Socioeconomic status was inferred from neighborhood income profiles as recorded in official 1996 Canadian census data (16). To control for variations in severity of illness upon admission, we used variables obtained from the Ontario AMI mortality prediction rule. The rule shows an area under the receiver-operating curve of 0.77 in validation data sets (13).

Outcomes. We examined procedural waiting times and adverse outcomes (urgent or emergent cardiac re-admissions, mortality, and hospital bed-days) at one year after MI. Because the exact date of referrals for procedures could not be determined from administrative data, the number of days between admission and initial revascularization procedure served as a waiting time surrogate (1,16,17).

We used urgent/emergent cardiac re-admissions as our primary measure of complications attributable to delayed revascularization. We excluded all elective hospitalizations. Urgent cardiac re-admissions were defined to include a primary diagnosis of recurrent AMI (ICD-9 code 410), angina (ICD-9 codes 411, 413), or congestive heart failure (ICD-9 code 428). About 97% of such re-admission codes are accompanied by a concomitant emergency room physician assessment (1), thus these codes do reflect urgent clinical need.

Because we examined only patients who survived to and after revascularization, the study could not assess differential mortality in the queue arising from delayed intervention. Hence, mortality was examined on an exploratory basis, focusing specifically on survival beyond revascularization. To ensure similar inter-group exposure periods to the risks of death after procedures, our mortality analysis was confined to those patients who underwent their revascularization during the index AMI hospitalization. We hypothesized that mortality would be similar in the two groups (1,18).

Last, we determined the number of hospital bed-days attributable to recurrent cardiac admissions as well as the cumulative number of hospital bed-days (for any reason) for each patient in our cohort.

Analysis. Categorical differences in patient characteristics were compared using chi-square tests and continuous differences compared with a *t* test. We adjusted for patient factors (sociodemographic characteristics and illness severity), physician factors (attending physician specialty), and hospital factors (on-site revascularization, geographic proximity to tertiary centers, academic affiliation, and hospital size) in multivariate analyses.

Procedural waiting times were examined using Poisson regression techniques. Time to first cardiac re-admission was assessed using Cox proportional hazards for: 1) the interval between discharge from the index admission and the first downstream revascularization procedure; and 2) the interval between the revascularization procedure (or hospital discharge if revascularization was undertaken during the index AMI admission) and the end of follow-up (i.e., one year after the index AMI). When assessing the one-year risk of cardiac re-admissions beyond intervention, patients were censored at the time of death, if mortality occurred before the first year after the index AMI. All multivariate analyses were constructed in a similar fashion using backward stepwise regression techniques (forcing age, gender, and illness severity into the model). We also undertook a pre-specified subgroup analysis (for patients of age 65 years and older) to determine whether differences in the use of evidence-based therapies (defined as aspirin, beta-blockers, angiotensin-converting enzyme [ACE] inhibitors, HMG-CoA reductase inhibitors, and the withholding of calcium-channel blockers) had any impact on inter-hospital variations in the risk of recurrent cardiac admissions.

To confirm the robustness of our results, our analyses were repeated using hierarchical logistic and Poisson regression (1,19). The results were similar with different statistical techniques. Consistent with our preference for modeling re-admission and mortality outcomes as functional hazards rather than as binary outcome variables, we present only the findings of our traditional Cox proportional hazard and Poisson regression models because of space limitations.

Statistical significance was defined as $p < 0.05$ for all analyses. Multilevel analyses were implemented using HLM version 5. SAS statistical software (version 8.2, SAS Institute Inc., Cary, North Carolina) was used for all remaining statistical analyses.

RESULTS

Table 1 illustrates that patients admitted to invasive institutions with on-site revascularization services tended to have higher cardiac severity and greater co-morbidities than those admitted to non-invasive hospitals. Although prescription rates among the elderly for most evidence-based pharmacotherapies were similar between hospital groups, elderly patients from non-invasive hospitals were significantly more likely to be discharged while receiving calcium-channel blockers and nitrates than those from invasive institutions. Table 2 illustrates the breakdown of sociodemographic and clinical characteristics for patients receiving surgical (compared with percutaneous) revascularization at either type of institution. Patients undergoing bypass sur-

Table 1. Baseline characteristics of the AMI Patients in Ontario Referred for Revascularization Procedures Between 1994 and 1998, According to Invasive and Non-Invasive Hospitals*

Variables	Invasive Hospitals (N = 2,198)	Non-Invasive Hospitals (N = 12,968)	p Value
Patient factors			
Demographic			
Age, yrs	61.3	60.5	0.002
Male gender, %	73.8	73.9	0.94
Average household income, $†	21,762	21,049	< 0.001
Cardiogenic shock, %	0.82	0.54	0.11
Clinical status at admission			
Congestive heart failure, %	13.7	10.1	< 0.001
Pulmonary edema, %	0.45	0.75	0.13
Cardiac dysrhythmia, %	15.0	8.7	< 0.001
Malignancy, %	0.73	0.76	0.86
Diabetes with complications, %	2.1	1.4	0.03
Stroke, %	1.64	1.44	0.48
Acute renal insufficiency, %	0.82	0.27	< 0.001
Chronic renal insufficiency, %	3.4	0.83	< 0.001
Canadian Cardiovascular Society class‡			
I–III, %§	28.3	36.5	< 0.001
IVA, %	23.4	21.6	
IVB, %	31.5	26.9	
IVC, %	16.9	14.9	
Coronary anatomy‡			
Isolated left main disease, %	15.8	14.2	0.19
High risk anatomy, %‖	82.0	78.2	0.01
One or two vessel disease, %¶	18.0	21.8	
Left ventricular dysfunction‡			
Calculated urgency‡			
Moderate or severe, %	40.1	33.4	< 0.001
Mild or none, %	60.0	66.6	
Recommended maximum waiting times (median days)	26.8 (13)	29.3 (13)	0.04
Proportion of bypass surgery within recommended maximum waiting times, %	59.2	53.1	< 0.001
Length of hospital stay#			
Mean number of days (median)	11.4 (9)	12.4 (9)	< 0.001
Medication use**			
Aspirin, %	69.5	68.4	0.51
Beta blockers, %	72.8	69.9	0.07
Calcium channel blockers, %	30.3	38.1	< 0.001
HMG-CoA reductase inhibitors, %	31.0	33.0	0.25
ACE inhibitors, %	49.9	47.2	0.12
Nitrates, %	67.8	73.1	0.001

*Invasive hospitals = hospitals with on-site angiography + revascularization facilities. Noninvasive hospitals = hospitals without on-site angiography + revascularization facilities. †Average household income (in Canadian dollars) was obtained from 1996 Canadian census data and corresponds to the Forward Sortation Area of the residents. ‡Among 7,648 bypass surgery (98.4% of the total patients receiving bypass surgery). §Canadian Cardiovascular Society classes I–IV, A, B, C as described elsewhere (14). ‖High-risk coronary anatomy = left main stenosis, 3-vessel disease (with or without proximal LAD stenosis), or 2-vessel disease with proximal LAD stenosis. ¶One vessel disease (with or without proximal LAD stenosis) or two vessel disease without proximal LAD stenosis. #Length of hospital stay during the index admission includes in-hospital transfers and applies to all 15,166 AMI patients in the cohort. **Medication use at 90-days following discharge from the index AMI admission and applies to patients 65 years of age and older.

ACE = angiotensin-converting enzyme; LAD = left anterior descending; AMI = acute myocardial infarction.

gery differed systematically from those undergoing angioplasty, regardless of whether the initial site of admission was an invasive or non-invasive hospital.

Utilization rates of revascularization. Compared with those in non-invasive hospitals, patients admitted to invasive hospitals were more likely to receive angioplasty (59.8% vs. 46.9%, $p < 0.001$), with mirror differences in bypass surgery use after MI. The differential use of angioplasty at invasive compared with non-invasive hospitals persisted after adjusting for patient factors (adjusted odds ratio [OR]: 1.85; 95% confidence interval [CI]: 1.68 to 2.04, $p < 0.001$) and specialty characteristics of the attending physician (adjusted OR: 1.75; 95% CI: 1.59 to 1.94, $p < 0.001$).

Waiting times for revascularization. Median waiting times for revascularization were shorter at invasive hospitals (Table 3; 12 days vs. 48 days, $p < 0.001$). After adjusting for

Table 2. The Relationship Between Baseline Characteristics and the Odds Ratio (± 95% Confidence Interval) of Receiving CABG (vs. PTCA) Among Patients Hospitalized With AMI at Invasive and Non-Invasive Institutions Between 1994 and 1998

Variables	Invasive Hospital (n = 2,198)	Non-Invasive Hospitals (n = 12,968)
Patient factors		
Demographic		
Youngest (20–49 yrs old) vs. others	0.47 (0.36–0.60)	0.41 (0.37–0.46)
Oldest (75+ yrs old) vs. others	1.11 (0.87–1.43)	1.42 (1.26–1.61)
Female gender (%)	0.67 (0.55–0.82)	0.80 (0.74–0.86)
Lowest socioeconomic quintile vs. others†	1.00 (0.81–1.24)	1.00 (0.92–1.09)
Highest socioeconomic quintile vs. others†	0.61 (0.49–0.76)	0.90 (0.83–0.99)
Clinical status at admission		
Lowest risk quartile‡ vs. others	0.54 (0.43–0.67)	0.53 (0.49–0.58)
Highest risk quartile‡ vs. others	1.59 (1.31–1.93)	1.69 (1.56–1.83)

*Invasive hospitals = hospitals with on-site angiography + revascularization facilities. Non-invasive hospitals = hospitals without on-site angiography + revascularization facilities. †Average household income (in Canadian dollars) was obtained from 1996 Canadian census data and corresponds to the Forward Sortation Area of the residents. ‡Risk quartile is derived using the clinical variables derived from the Ontario Myocardial Infarction mortality prediction rule. They include: congestive heart failure, cardiogenic shock, pulmonary edema, arrythmias, diabetes with complications, stroke, malignancy, acute renal failure, chronic renal failure (13).

AMI = acute myocardial infarction; CABG = coronary artery bypass graft; PTCA = percutaneous transluminal coronary angioplasty.

patient and physician factors, hospitals with on-site revascularization facilities still showed a 62.1% relative decrease in the adjusted number of mean days waiting for revascularization ($p < 0.001$).

Shorter waiting times occurred in part because of a higher prevalence of in-hospital procedures, particularly angioplasty, performed during the index AMI admission (adjusted OR: 2.00; 95% CI: 1.76 to 2.28, $p < 0.001$). Also, when

Table 3. Waiting Times of Patients Revascularized Within One Year After AMI for Patients Hospitalized at Invasive Versus Non-Invasive Institutions Between 1994 and 1998*

Variables Waiting Times	Invasive Hospitals	Non-Invasive Hospitals	p Value
Angioplasty			
The percentage (risk ratio) of angioplasty performed during the index hospitalization vs. after discharge	70.6/29.4 (2.40)	40.5/59.5 (0.68)	< 0.001
Mean (median) number of days waiting in-hospital for angioplasty	6.1 (5)	11.9 (11)	< 0.001
Mean (median) number of days waiting for angioplasty after hospital discharge	102.9 (73.0)	114.0 (96.5)	< 0.001
Mean (median) number of days between AMI and angioplasty	37.0 (8)	77.4 (31)	< 0.001
Bypass surgery			
The percentage (risk ratio) of bypass surgery performed during the index hospitalization vs. after discharge	45.6/54.4 (0.84)	31.1/68.9 (0.45)	< 0.001
The proportion of patients receiving bypass surgery within the recommended maximum waiting times†	59.2	53.1	< 0.001
Mean (median) number of days waiting in-hospital for bypass surgery	10.0 (9)	16.2 (15)	< 0.001
Mean (median) number of days waiting for any revascularization after hospital discharge	112.6 (89)	129.2 (112)	< 0.001
Mean (median) number of days waiting between AMI and any revascularization	51.8 (12)	93.4 (48)	< 0.001
Any revascularization			
The percentage (risk ratio) of revascularization performed during the index hospitalization vs. after discharge	60.8/39.2 (1.55)	35.6/64.4 (0.55)	< 0.001
Mean (median) number of days waiting in-hospital for any revascularization	7.3 (6)	13.9 (13)	< 0.001
Mean (median) number of days waiting for any revascularization after hospital discharge	112.6 (89)	129.2 (112)	< 0.001
Mean (median) number of days waiting between AMI and any revascularization	51.8 (12)	93.4 (48)	< 0.001

*Invasive hospitals = hospitals with on-site angiography + revascularization facilities. Non-invasive hospitals = hospitals without on-site angiography + revascularization facilities. †As derived using clinical data obtained from the Ontario coronary artery bypass surgery triage registry.

AMI = acute myocardial infarction.

Table 4. Outcomes of Patients Revascularized Within One Year After AMI at Invasive Versus Non-Invasive Institutions Between 1994 and 1998

Variables Adverse Outcomes	Invasive Hospitals	Non-Invasive Hospitals	p Value
Before revascularization†			
At least one recurrent cardiac admission per 100 AMI patients	31.7	45.6	< 0.001
MI readmissions rate per 100 AMI patients	5.8	11.6	< 0.001
Angina re-admission rate per 100 AMI patients	6.9	20.6	< 0.001
CHF re-admission rate per 100 AMI patients	1.5	2.3	0.02
The total number of recurrent cardiac admissions per 100 AMI patients	41.5	68.9	< 0.001
Hospital bed-days due to recurrent cardiac admissions per 100 AMI patients	379	517	< 0.001
After revascularization‡			
At least one recurrent cardiac admission per 100 AMI patients	12.5	12.8	0.72
MI re-admission rate per 100 AMI patients	3.4	2.4	0.006
Angina re-admission rate per 100 AMI patients	7.6	8.1	0.49
CHF re-admission rate per 100 AMI patients	3.0	3.4	0.32
The total number of recurrent cardiac admissions per 100 AMI patients	20.7	18.8	0.56
Hospital bed-days due to recurrent cardiac admissions per 100 AMI patients	128	113	0.27
At any time§			
At least one recurrent cardiac admission per 100 AMI patients	22.9	37.5	< 0.001
MI re-admission rate per 100 AMI patients	8.6	13.6	< 0.001
Angina re-admission rate per 100 AMI patients	13.8	26.3	< 0.001
CHF re-admission rate per 100 AMI patients	4.1	5.2	0.03
The total number of recurrent cardiac admissions per 100 AMI patients	35.9	62.8	< 0.001
Hospital bed-days due to recurrent cardiac admissions per 100 AMI patients	274	445	< 0.001
Cumulative number of days in-hospital for any reason (including the index AMI) per 100 AMI patients	2,103	2,487	< 0.001

*Invasive hospitals = hospitals with on-site angiography + revascularization facilities. Non-invasive hospitals = hospitals without on-site angiography + revascularization facilities. †Adverse events (urgent cardiac readmissions) before the revascularization procedure among patients discharged alive from the index AMI admission. ‡Adverse events (urgent cardiac readmissions) after revascularization (during the first year after AMI) among patients discharged alive from hospital. §Any adverse event before or after the index AMI admission.

AMI = acute myocardial infarction; CHF = congestive heart failure.

patients admitted to non-invasive institutions were slated for a procedure on the index admission, they waited for transfers to invasive institutions (Table 3).

Adverse outcomes before revascularization. Among the 4,077 patients (44.3% of the eligible cohort) urgently re-admitted to hospital before revascularization, 1,075 (26.4%) had already received coronary angiography after their AMI. The median time interval between a cardiac re-admission and revascularization was 18 days. As illustrated in Table 4, patients discharged from invasive hospitals before their revascularization procedures experienced fewer adverse cardiac events (41.5% vs. 68.9%, $p < 0.001$) and fewer days in-hospital (379 per 100 patients vs. 517 per 100 patients, $p < 0.001$) than those discharged from non-invasive institutions. An admission to an invasive hospital was associated with a 30% reduction in the risk of urgent cardiac re-admissions before revascularization (adjusted relative risk [RR] for invasive hospitals: 0.70, 95% CI: 0.62 to 0.80, $p < 0.001$) (Figs. 2 and 3). Subgroup analysis demonstrated similar outcome benefits across age strata and independent of the use of outpatient evidence-based pharmacotherapies such as beta-blockers, aspirin, ACE inhibitors, and statins (Fig. 3).

Adverse outcomes after revascularization. Once patients had received their revascularization procedures, outcomes were similar between invasive and non-invasive hospitals (Table 4). Although post-procedural crude re-infarction rates were marginally higher at invasive hospitals (3.4% vs. 2.4%, $p = 0.006$), there were no significant differences after adjusting for baseline clinical factors (adjusted RR: 1.18; 95% CI: 0.91 to 1.54, $p = 0.22$). Inter-hospital group similarities in post-procedural non-fatal outcomes were not only independent of baseline characteristics (Fig. 2) but also similar after adjusting for variations in the use evidence-based outpatient pharmacotherapies (Fig. 3).

Given that all revascularized patients were followed up for one year beginning from their initial AMI presentation, longer outpatient waiting times would have directly resulted in shortened exposure times to the risk of adverse events beyond revascularization (median exposure periods to the risk of events after procedures were 342 days per 100 patients vs. 275 days per 100 patients at invasive vs. non-invasive hospitals, $p < 0.001$). Accordingly, these analyses were repeated among a subgroup of patients with similar post-procedural exposure periods by confining the sample to those who underwent revascularization during the initial AMI admission. Our results were similar. Outcomes after revascularization did not significantly vary between the two hospital groups (adjusted RR for invasive hospitals: 0.88, 95% CI: 0.75 to 1.04, $p = 0.14$).

Among patients revascularized during the index hospitalization, crude and adjusted one-year mortality rates were equivalent between institution types (crude one-year mortality rates at invasive and non-invasive hospitals: 5.8% and 5.3% respectively, $p = 0.41$; adjusted RR for invasive hospitals: 1.03, 95% CI: 0.79 to 1.35, $p = 0.81$).

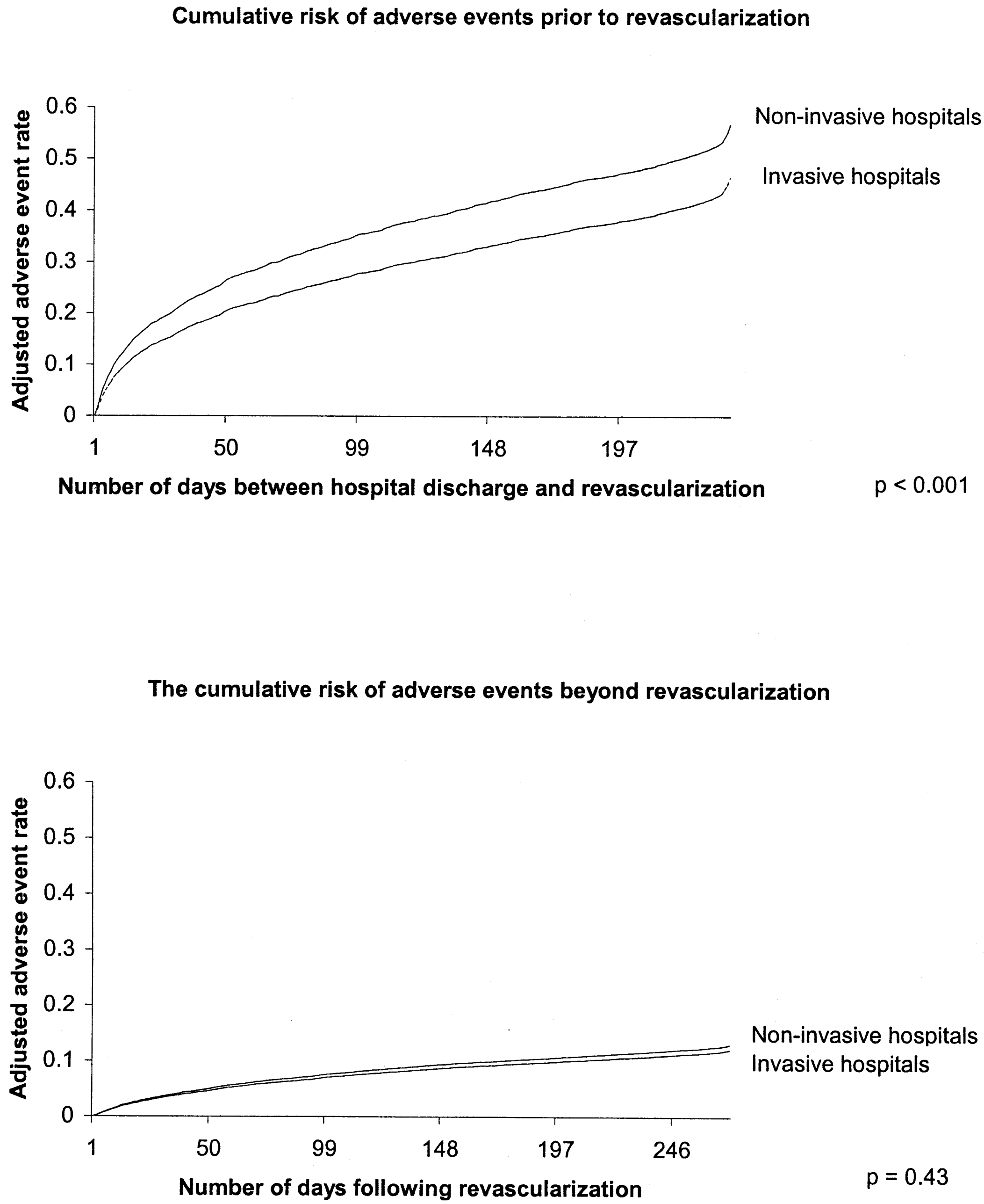

Figure 2. Cumulative risk of adverse events before and after revascularization. Adverse events are defined as the recurrent cardiac hospitalization (first recurrent admission for angina, myocardial infarction, or congestive heart failure).

Cumulative adverse outcomes (before or after revascularization). In total, when ignoring the timing of revascularization, invasive hospitals were associated with a 36% reduction in the risk of death or recurrent cardiac admission (Adjusted RR for invasive hospitals: 0.64, 95% CI: 0.59 to 0.70, $p < 0.001$). Fewer hospitalizations resulted in an average 384 fewer days in-hospital per 100 patients over the first year of the AMI (Table 4). After adjusting for all other factors, revascularization when performed during the index AMI admission was associated with a 65.9% reduction in the risk of death or recurrent hospitalization ($p < 0.001$).

DISCUSSION

Among Ontario patients receiving revascularization after AMI, those admitted to hospitals with on-site revascularization facilities were preferentially referred to angioplasty, whereas patients admitted to hospitals without on-site revascularization facilities were more likely to receive bypass surgery. Given that the vast majority of patients who were initially admitted to invasive hospitals were able to receive their angioplasty procedure during the index AMI admission, overall revascularization waiting times were, on average, 62.1% shorter at hospitals with on-site revasculariza-

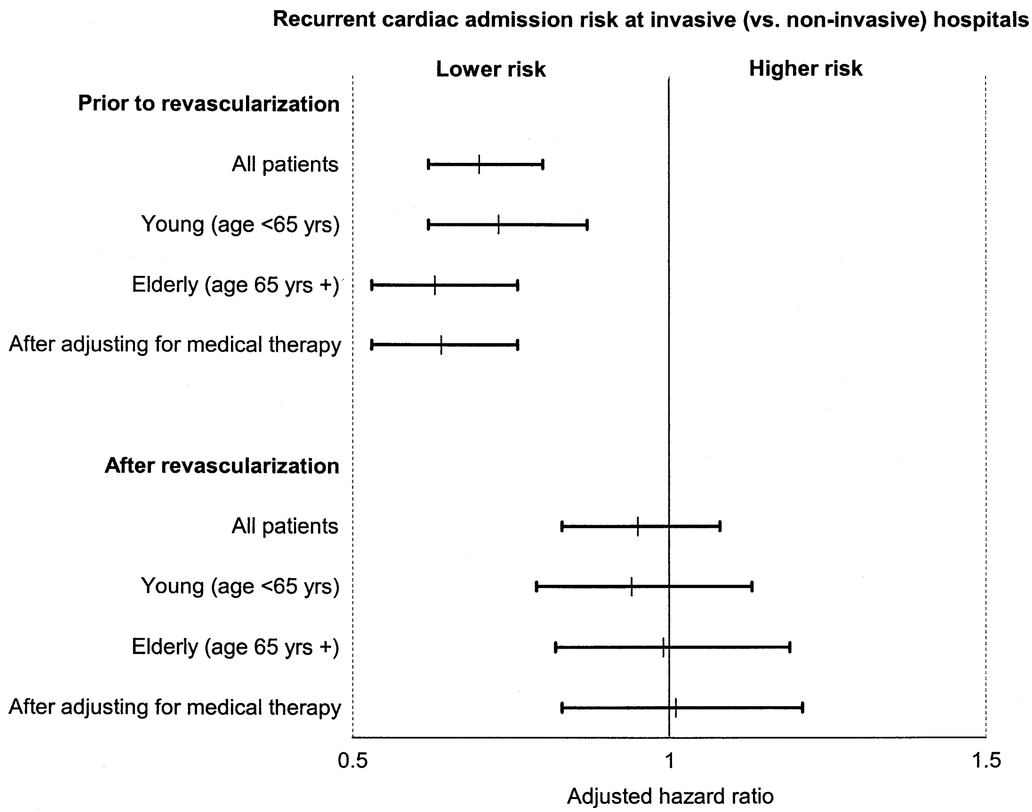

Figure 3. Adjusted risk of recurrent cardiac admissions at invasive (vs. non-invasive) hospitals. All models have been adjusted for sociodemographic characteristics, clinical severity, attending physician specialty, and hospital academic affiliation, using Cox proportional hazards. These models adjusted for variations in the use of medical therapies and pertain to patients 65 years of age and older. Medications include the use of aspirin, beta-blockers, angiotensin-converting enzyme inhibitors, HMG-CoA reductase inhibitors, and the absence of calcium-channel blockers at hospital discharge.

tion capacity than those without. The observed differences were associated with a 36% decrease in the adjusted risk of cardiac re-admissions after AMI—a difference largely attributable to two factors: 1) fewer patients in the outpatient queue originating from invasive hospitals because of earlier interventions performed during the index AMI hospitalization; and 2) a lower event rate in the outpatient queue among those few patients discharged from invasive hospitals who had yet to receive their revascularization during the index admission. Differences in pre-procedural re-admissions resulted in significantly fewer patient days in hospital and probably lower hospital expenditures as a result. Conversely, there were no significant outcome differences between the two hospital groups once revascularization had been performed.

Revascularization modality and on-site procedural capacity. Our results are consistent with other interventional studies that have demonstrated a positive relationship between utilization rates of catheter-based invasive cardiac procedures and on-site revascularization capacity after AMI (1,20). To our knowledge, however, this is the first study to demonstrate that such institutional factors also influence the choice of which revascularization modality is undertaken after AMI. Inter-hospital group differences in the revascularization modality of choice were predominantly driven by the angioplasty preferences of cardiologists practicing within invasive compared with non-invasive hospitals. This result is consistent with limited available evidence, which demonstrates that referral rates for invasive cardiac procedures do vary according to cardiology subspecialty (invasive vs. non-invasive cardiologists) (10).

Early versus delayed interventions and outcomes. Available evidence from clinical trials has demonstrated similar efficacies between angioplasty and bypass surgery after revascularization (18). Indeed, early revascularization, not modality, best explained the non-fatal outcome advantages associated with invasive tertiary hospitals after AMI in our study. Our results therefore highlight the importance of timely intervention as an independent predictor of outcomes after AMI (5). Facilitated access to angioplasty benefited the majority of patients admitted to invasive hospitals by allowing physicians to intervene early during the index AMI hospitalization. Fewer downstream events among those who had not yet undergone revascularization during the index AMI admission suggest that physicians had already selected higher-risk patients for intervention, leaving those at lower risk of adverse events for discharge on medical therapy alone.

Although it is possible that variations in the use of other factors (e.g., intensity of outpatient follow-up or cardiac rehabilitation services) may have partly accounted for the outcome differences observed between invasive and non-invasive centers in our study (21), we believe the relationship between procedural waiting times and outcomes is compelling for several reasons. First, this study included only those patients selected for revascularization. Second, the short-term outcome advantages associated with invasive hospitals existed only during the interval of time in which patients were awaiting revascularization. Conversely, no significant outcome benefits associated with invasive hospitals were apparent beyond revascularization. Third, the timeliness of intervention itself was a predictor of outcome. Finally, neither other proxies for better process of care (e.g., hospitals' academic affiliations) nor the use of evidence-based pharmacotherapy could account for the outcome differences between invasive and non-invasive hospitals in our study.

Many studies examining the outcome advantages associated with early aggressive interventions after AMI have yielded inconsistent results (1,4,8,22,23). For example, in one recent Swedish study, Stenestrand and Wallentin (8) demonstrated that early revascularization (compared with delayed conservative strategies) was associated with a 50% RR reduction for mortality at one-year after AMI at hospitals with both low and high revascularization volume strategies. Yet, more recently, a study examining 25,515 U.S. patients enrolled in the Global Use of Streptokinase and tPA (alteplase) for Occluded coronary arteries (GUSTO)-I trial demonstrated no mortality benefits associated with on-site revascularization (22). The advantages for invasive hospitals seen in our study may therefore specifically reflect the effects of long waiting times for revascularization when patients are admitted with AMI to non-invasive hospitals in Canada.

More specifically, studies designed to compare early aggressive versus delayed conservative strategies have in essence compared two process factors simultaneously: higher versus lower utilization and early versus delayed intervention. We took as given a rate of intervention after AMI that would be judged moderate by international standards, confined our analysis to those who actually received revascularization, and therefore, focused in on only one process factor—facilitated versus delayed access to intervention. As a corollary, the baseline risk of adverse outcomes diminishes exponentially in the days and weeks that follow initial presentation with an acute coronary syndrome (1). Thus, as patients are followed up over time and stabilize, the initial risk and related differences in event rates is washed out. In our study, the median revascularization waiting time for patients admitted to non-invasive community hospitals in Ontario was 48 days, a significantly longer median waiting time than that experienced for most patients who are referred for revascularization in the U.S. (24).

Our results suggest that policy makers and system managers must devise ways to facilitate revascularization in a timely fashion for heart attack patients admitted to hospitals without on-site revascularization capacity. Although event rates for patients awaiting coronary angiography and bypass surgery in Ontario are low, especially for patients who are prioritized appropriately according to clinical urgency (25,26) our study suggests that patients with recent AMI are a particularly high-risk subgroup. Accordingly, policy makers must improve the efficiency of hospital transfers in order to revascularize a greater number of potentially vulnerable patients during the index AMI hospitalization.

Study limitations. There are limitations to our study. First, we used a surrogate measure of waiting times. However, it is a defensible and consistent surrogate. Recent evidence suggests that the time interval between presentation of acute coronary syndromes and revascularization is an important independent prognostic measure of outcomes (5,7,8). Second, not all patients who suffered adverse events may have been waiting for a procedure; instead, the adverse event itself may have triggered referral for a procedure. Nonetheless, our results similarly applied to the subgroup of patients who had already received angiography and who were likely therefore to be in the revascularization queue. Third, we had limited data on clinical characteristics of patients undergoing angioplasty. However, we did examine the symptom status and anatomic characteristics of those patients receiving bypass surgery and found that such factors were distributed in similar proportions between invasive and non-invasive institutions. Furthermore, with few exceptions, the case-mix distribution of patients undergoing angioplasty versus bypass surgery was similar between institution groups. Thus, it is unlikely that additional clinical detail would have accounted for the observed differences in selection, waiting times, and outcomes. Moreover, our sample included all patients receiving revascularization after AMI in Ontario and therefore is highly representative of the Canadian population.

Conclusions. Our findings suggest that institutional characteristics (i.e., on-site procedural capacity) are important in determining the modality and timing of revascularization after AMI. Delays in revascularization for patients with AMI admitted to hospitals without on-site revascularization facilities are associated with a higher risk of adverse events and lengthier hospitalizations. Policy makers and clinicians should ensure timely access for patients awaiting revascularization after AMI to minimize adverse outcomes before surgery or angioplasty.

Reprint requests and correspondence: Dr. David A. Alter, Institute for Clinical Evaluative Sciences, G106-2075 Bayview Avenue, Toronto, Ontario M4N 3M5, Canada. E-mail: david.alter@ices.on.ca.

REFERENCES

1. Alter DA, Naylor CD, Austin PC, Tu JV. Long-term MI outcomes at hospitals with or without on-site revascularization. JAMA 2001; 285:2101–8.
2. Chapple A, Gatrell A. Variations in use of cardiac services in England: perceptions of general practitioners, general physicians and cardiologists. J Health Serv Res Policy 1998;3:153–8.

3. Llevadot J, Giugliano RP, Antman EM, et al. Availability of on-site catheterization and clinical outcomes in patients receiving fibrinolysis for ST-elevation myocardial infarction. Eur Heart J 2001;22:2104–15.
4. Feit F, Mueller HS, Braunwald E, et al. Thrombolysis In Myocardial Infarction (TIMI) phase II trial: outcome comparison of a "conservative strategy" in community versus tertiary hospitals. The TIMI Research Group. J Am Coll Cardiol 1990;16:1529–34.
5. FRagmin and Fast Revascularisation during InStability in Coronary artery disease Investigators. Invasive compared with noninvasive treatment in unstable coronary-artery disease: FRISC II prospective randomised multicentre study. Lancet 1999;354:708–15.
6. Holmes DRJ. Acute coronary syndromes: extending medical intervention for five days before proceeding to revascularization. Am J Cardiol 2000;86:36M–41M.
7. Cannon CP, Weintraub WS, Demopoulos LA, et al. Comparison of early invasive and conservative strategies in patients with unstable coronary syndromes treated with the glycoprotein IIb/IIIa inhibitor tirofiban. N Engl J Med 2001;344:1879–87.
8. Stenestrand U, Wallentin L. Early revascularisation and 1-year survival in 14-day survivors of acute myocardial infarction: a prospective cohort study. Lancet 2002;359:1805–11.
9. White HD. Optimal treatment of patients with acute coronary syndromes and non–ST-elevation myocardial infarction. Am Heart J 1999;138:S105–14.
10. Di Salvo TT, Paul SD, Lloyd-Jones D, et al. Care of acute myocardial infarction by noninvasive and invasive cardiologists: procedure use, cost and outcome. J Am Coll Cardiol 1996;27:262–9.
11. Chester M, Chen L, Kaski JC. Identification of patients at high risk for adverse coronary events while awaiting routine coronary angioplasty. Br Heart J 1995;73:216–22.
12. Cardiac Care Network of Ontario. Target Setting Working Group. Final Report and Recommendations. October 2000.
13. Tu JV, Austin PC, Walld R, Roos L, Agras J, McDonald KM. Development and validation of the Ontario acute myocardial infarction mortality prediction rules. J Am Coll Cardiol 2001;37:992–7.
14. Alter DA, Austin P, Tu JV. Use of coronary angiography, angioplasty and bypass surgery after acute myocardial infarction in Ontario. In: Naylor CD, Slaughter PM, editors. Cardiovascular Health and Services in Ontario: An ICES Atlas. Toronto: Institute for Clinical Evaluative Sciences, 1999:141–64.
15. Naylor CD, Sykora K, Jaglal SB, Jefferson S. Waiting for coronary artery bypass surgery: population-based study of 8,517 consecutive patients in Ontario, Canada. The Steering Committee of the Adult Cardiac Care Network of Ontario. Lancet 1995;346:1605–9.
16. Alter DA, Naylor CD, Austin P, Tu JV. Effects of socioeconomic status on access to invasive cardiac procedures and on mortality after acute myocardial infarction. N Engl J Med 1999;341:1359–67.
17. Johansen H, Nair C, Luling M, Wolfson M. Revascularization and heart attack outcomes. Health Rep 2002;13:35–46.
18. The Bypass Angioplasty Revascularization Investigation (BARI) Investigators. Comparison of coronary bypass surgery with angioplasty in patients with multivessel disease. N Engl J Med 1996;335:217–25.
19. Snijders TAB, Boster RJ. Multilevel Analysis: An Introduction to Basic and Advanced Multilevel Modeling. London: Sage Publications, 1999.
20. Blustein J. High-technology cardiac procedures. The impact of service availability on service use in New York State. JAMA 1993;270:344–9.
21. Mark DB, Naylor CD, Hlatky MA, et al. Use of medical resources and quality of life after acute myocardial infarction in Canada and the United States. N Engl J Med 1994;331:1130–5.
22. Mehta RH, Criger DA, Granger CB, et al. Patient outcomes after fibrinolytic therapy for acute myocardial infarction at hospitals with and without coronary revascularization capability. J Am Coll Cardiol 2002;40:1034–40.
23. Batchelor WB, Peterson ED, Mark DB, et al. A comparison of U.S. and Canadian cardiac catheterization practices in detecting severe coronary artery disease after myocardial infarction: efficiency, yield and long-term implications. J Am Coll Cardiol 1999;34:12–9.
24. Carroll RJ, Horn SD, Soderfeldt B, James BC, Malmberg L. International comparison of waiting times for selected cardiovascular procedures. J Am Coll Cardiol 1995;25:557–63.
25. Maziak DE, Rao V, Christakis GT, et al. Can patients with left main stenosis wait for coronary artery bypass grafting? Ann Thorac Surg 1996;61:552–7.
26. Natarajan MK, Mehta SR, Holder DH, et al. The risks of waiting for cardiac catheterization: a prospective study. CMAJ 2002;167:1233–40.